CLAIMS

What is claimed:

1. A method of forming a photolithographic pattern comprising the steps of:

providing a surface having a multi-photon-specific photoinitiator material disposed thereon;

irradiating in a first irradiation pattern at least a portion of the multi-photon-specific photoinitiator material with a first wavelength of light capable of electronically exciting the irradiated portion of the multi-photon-specific photoinitiator to a first excited electronic state;

irradiating in a second irradiation pattern at least a portion of the multi-photon-specific photoinitiator material with a second wavelength of light, the second wavelength of light being capable of electronically exciting the portion of the multi-photon-specific photoinitiator irradiated by both the first wavelength of light and the second wavelength of light to a second excited electronic state, the multi-photon-specific photoinitiator material in the second excited electronic state being capable of undergoing a chemical reaction to form a photolithographic pattern on the surface.

2. The method of claim 1, wherein the surface comprises one or more layers of material on a semiconductor substrate.

3. The method of claim 1, wherein the multi-photon-specific photoinitiator material comprises benzil.

4. The method of claim 1, wherein the multi-photon-specific photoinitiator material comprises phenothiazine.

5. The method of claim 1, wherein the first wavelength of light comprises light having a wavelength in the range between about 100 nanometers and 1100 nanometers.

6. The method of claim 1, wherein the second wavelength of light comprises light having a wavelength in the range between about 100 nanometers and 1100 nanometers.

7. The method of claim 1, wherein the first excited electronic state comprises a singlet state.

8. The method of claim 1, wherein the second excited electronic state comprises a triplet state.

9. The method of claim 1, wherein:

the step of irradiating in a first irradiation pattern further comprises imaging the first wavelength of light onto the multi-photon-specific photoinitiator material through a first photolithographic mask; and

the step of irradiating in a second irradiation pattern further comprises imaging the second wavelength of light onto the multi-photon-specific photoinitiator material through a second photolithographic mask different from the first photolithographic mask.

10. The method of claim 1, wherein the chemical reaction comprises acid generation.

11. The method of claim 1, wherein the chemical reaction comprises free radical generation.

12. The method of claim 1, wherein the chemical reaction comprises polymerization.

13. The method of claim 1, wherein the chemical reaction comprises generating a material resistant to acid when contacted with a developing solution.

14. The method of claim 1, wherein the photolithographic pattern on the surface comprises an etching mask for the surface.

15. The method of claim 1, wherein the photolithographic pattern comprises at least one feature having a dimension smaller than $\lambda/(2NA)$, where λ is the first wavelength of light or the second wavelength of light, whichever wavelength is shorter, and NA is the numerical aperture of an imaging system used to irradiate the multi-photon-specific photoinitiator with the light of wavelength λ.

16. The method of claim 1, further comprising the step of:

irradiating in a third irradiation pattern at least a portion of the multi-photon-specific photoinitiator material with a third wavelength of light, different from the first wavelength of light and the second wavelength of light, the third wavelength of light capable of electronically exciting the portion of the multi-photon-specific photoinitiator to be irradiated by both the first wavelength of light and the third wavelength of light to a third excited electronic state having an energy greater than the first excited electronic state but less than the second excited electronic state, wherein the second wavelength of light is capable of electronically exciting the portion of the multi-photon-specific photoinitiator irradiated by the first wavelength of light, the third wavelength of light and the second wavelength of light to a second excited electronic state.

17. A method of semiconductor fabrication capable of permitting the formation of an imaged feature having a dimension smaller than $\lambda/(2NA)$, where λ is the smallest

wavelength of imaging light, and NA is the numerical aperture of the imaging system, comprising the steps of:

providing a surface having a multi-photon-specific photoinitiator material disposed thereon;

imaging in a pattern each of two or more different wavelengths of light onto the multi-photon-specific photoinitiator material to form a photolithographic pattern on the surface where each of the patterns of the two or more different wavelengths of light overlap.

18. The method of claim 17, wherein the photolithographic pattern comprises at least one feature having a dimension smaller than $\lambda/(2NA)$, where λ is the shortest of the two or more wavelengths of light, n is the number of different wavelengths of light imaged in a pattern onto the multi-photon-specific photoinitiator material, and NA is the numerical aperture of an imaging system used to irradiate the multi-photon-specific photoinitiator with the light of wavelength λ.

19. The method of claim 17, wherein the surface comprises one or more layers of material on a semiconductor substrate.

20. The method of claim 17, wherein the step of imaging further comprises:

irradiating in a first irradiation pattern at least a portion of the multi-photon-specific photoinitiator material with a first wavelength of light capable of electronically exciting the irradiated portion of the multi-photon-specific photoinitiator to a first excited electronic state; and

irradiating in a second irradiation pattern at least a portion of the multi-photon-specific photoinitiator material with a second wavelength of light, different from the first wavelength of light, the second wavelength of light capable of electronically exciting the portion of the multi-photon-specific photoinitiator irradiated by both the first wavelength of light and the second

wavelength of light to a second excited electronic state, the multi-photon-specific photoinitiator material in the second excited electronic state capable of undergoing a chemical reaction to form a photolithographic pattern on the surface.

21. The method of claim 20, wherein the chemical reaction comprises acid generation.

22. The method of claim 20, wherein the chemical reaction comprises free radical generation.

23. The method of claim 20, wherein the chemical reaction comprises polymerization.

24. The method of claim 20, wherein the chemical reaction comprises generating a material resistant to acid when contacted with a developing solution.

25. The method of claim 17, wherein the multi-photon-specific photoinitiator material comprises benzil.

26. The method of claim 17, wherein the multi-photon-specific photoinitiator material comprises phenothiazine.

27. The method of claim 17, wherein the photolithographic pattern on the surface comprises an etching mask for the surface.

28. A method of forming a photolithographic pattern comprising the steps of:

providing a surface having a multi-photon-specific photoinitiator material disposed thereon;

irradiating in a first irradiation pattern at least a portion of the multi-photon-specific photoinitiator material with a first modality of light;

irradiating in a second irradiation pattern at least a portion of the multi-photon-specific photoinitiator material with a second modality of light, different from the first modality of light, the second modality of light capable initiating a chemical reaction in the portion of the multi-photon-specific photoinitiator irradiated by both the first modality of light and the second modality of light to form a photolithographic pattern on the surface.

29. The method of claim 28, wherein a modality of light comprises one or more of wavelength, polarization, optical angular momentum state, and coherent light pulse width.

30. The method of claim 28, wherein the surface comprises one or more layers of material on a semiconductor substrate.

31. The method of claim 28, wherein the multi-photon-specific photoinitiator material comprises benzil.

32. The method of claim 28, wherein the multi-photon-specific photoinitiator material comprises phenothiazine.

33. The method of claim 28, wherein the photolithographic pattern on the surface comprises an etching mask for the surface.